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DEVELOP AND TEST FUEL CELL POWERED ON SITE INTEGRATED TOTAL ENERGY SYSTEMS: PHASE III, FULL-SCALE POWER PLANT DEVELOPMENT

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SECTION I. INTRODUCTION

Engelhard's objective under the present contract is to contribute substantially to the national fuel conservation program by developing a commercially viable and cost-effective phosphoric acid fuel cell powered on-site integrated energy system (OS/IES). The fuel cell offers energy efficiencies in the neighborhood of 40% of the lower heating value of available fuels in the form of electrical energy. By utilizing the thermal energy generated for heating, ventilating, and air-conditioning (HVAC), a fuel cell OS/IES could provide total energy efficiencies in the neighborhood of 80%. Also, the Engelhard fuel cell OS/IES, which is the objective of the present program, offers the important incentive of replacing imported oil with domestically produced fuel.

Engelhard has successfully completed the first two phases of this program. The culmination of the pre-commercialization program will be the integration of the fuel cell system into a total energy system for multi-family residential and commercial buildings. The mandate of the current Phase III effort is to develop a full-scale 50kW breadboard power plant module and to identify a suitable type of application site. An accomplished objective in Phase III was the integration and testing of the 5kW system whose components were developed during Phase II. In addition to the development and testing of this sub-scale system, scale-up activities have been carried out under Phase III. Throughout this program, continuing technology development activity will be maintained to assure that the performance, reliability, and cost objectives are attained.

SECTION II. TECHNICAL PROGRESS SUMMARY

TASK I - 5kW POWER SYSTEM DEVELOPMENT

The objective of this task was to complete integration of the 5kW components and sub-systems developed during Phase II.

Steady-load testing of the 5kW integrated system, with regular shutdowns, was completed during August 1983. Subsequently, load-following testing was carried out successfully, as the system was operated in the fully-automatic mode. (See the August-October 1983 Quarterly Report.)

Further testing of this integrated system will be conducted as time permits.

TASK II - ON-SITE SYSTEM APPLICATION ANALYSIS

The purpose of this task was to develop an application model for on-site integrated energy systems. The model considers fuel availability, costs, building types and sizes, power distribution requirements (electrical and thermal), waste heat utilization potential, types of ownership of the OS/IES, and grid connection vs. stand-alone operation. The work of this task was carried out under subcontract by Arthur D. Little, Inc. (ADL), and this work has been completed. The main conclusions are summarized in the May-July 1983 Quarterly Report.

TASK III - ON-SITE SYSTEM DEVELOPMENT

This task forms the core of the Phase III contract effort. Work under this task will result in the breadboard design of a system for an on-site application. The power plant will be designed for a rated output of 50kW (electrical) or some multiple thereof. The fuel processor and power conditioner will each be 50kW units, while the 50kW fuel cell will comprise two 25kW stacks. This task is accordingly broken down into four sub-tasks as follows:

III-1. Large Stack Development
III-2. Large Fuel Processor Development
III-3. Overall System Analysis
III-4. Overall System Design and Development

The 1984 activities under this contract are focusing on Sub-Task III.1 Further effort on the other sub-tasks will be carried cut under private sponsorship.

SUB-TASK 1. LARGE STACK DEVELOPMENT

Stack No. 1 in the 1984 series (25-cell, 13 in. x 23 in.) has been on load for about 4000 hours. Operation on synthetic reformate fuel (75% H_2, 24% CO_2, 1% CO; moisturized to about 10% H_2O) was initiated in early August. The current performance level is 0.59V per cell on average at 161mA/cm^2, reformate-air. The distribution of cell voltages and H_2-gains is shown in Figure 1 and Figure 2, respectively.

Stack No. 2 in the 1984 series (25-cell, 13 inch x 23 inch) has been on load for about 2900 hours. As in the case of Stack No. 1, operation on synthetic reformate fuel (75% H_2, 24% CO_2, 1% CO; moisturized to about 10% H_2O) was initiated in early August). The current performance level is 0.61V per cell on average at 161mA/cm^2, reformate-air. The distribution of cell voltages and H_2-gains is shown in Figure 3 and Figure 4, respectively.

Both stacks were adversely affected by a hydrogen supply interruption during August. This incident, caused by an unexpected gas delivery lapse over a weekend, resulted in both a hot no-load condition (1-1/2 hours) and a water soak (because of the fuel humidification stream remaining on during this period). Stack No. 1 lost about 10mV per cell on average as a result of this. About 2mV of this loss is attrbutable to an increase in H_2-gain.

Stack No. 2 also suffered ill-effects despite the fact that the stack-protection control system was operational for this stack, providing N_2 purge in place of both the fuel and air feeds upon the loss of hydrogen. However, the continuing flow of water in the humidification stream apparently caused a degree of soaking, especially as the temperature of the stack dropped. The performance loss resulted wholly from an increse in H_2-gain (to an average of 20-21mV per cell, compared to 10-11mV earlier).

The stack-protection control system was implemented for Stack No. 1 in late September. However, before the over-temperature/under-temperature sensor was installed, an unexplained coolant pump stoppage during an overnight period caused an excessively high stack temperature of about 500°F.

The stack was returned to its normal operating temperature the following morning when the coolant pump restarted normally. The stack suffered no overt damage; but, because of the excessive temperatures involved, it was shut down for inspection of manifold gaskets, coolant distribution hoses, etc. A minor leak was found in a Viton reactant gas manifold gasket; this gasket section was replaced, and the stack was restarted and returned to normal load.

The performance loss suffered by Stack No. 1 due to the severe over-temperature condition was surprisingly small. However, there was evidence of increasing H_2-gain in several cells over the course of October (especially Cell No. 24; see Figure 2). This apparently reflected a degree of electrolyte flooding of the anodes (loss of wetproofing effectiveness).

During the last week in October both stacks underwent a controlled shutdown (via the stack-protection control systems) in response to an unknown upset. An automatic restart was also effected for both stacks, and in each case there was no apparent performance loss.

SUB-TASK 2. LARGE FUEL PROCESSOR DEVELOPMENT

Activities related to the 50kW methanol processing sub-system have resumed. This hardware will be used to generate hydrogen for the 25kW stack test program.

SUB-TASK 3. OVERALL SYSTEM ANALYSIS

The Physical Sciences Inc. subcontract has been completed. Final reports involving the off-design and transient analysis portions of the work have been received. The corresponding computer modules have been integrated into the overall fuel cell system program, and these have been successfully utilized in-house.

SUB-TASK 4. OVERALL SYSTEM DESIGN AND DEVELOPMENT

The Trane Co. has completed work under its subcontract to Engelhard. The main conclusions of Trane's study with respect to the HVAC sub-system and the utilization of waste heat are summarized in the May-July 1983 Quarterly Report.

TASK IV - STACK TECHNOLOGY

The purpose of this task, which will continue throughout the contract, is to investigate new materials and component concepts through bench-testing and stack trials. The criteria for selecting activities under this task are the prospects for improved performance, reduced costs, or improved reliability. Improvements in the performance of electrocatalysts, generated under Engelhard-sponsored Task VI, are reported under Task IV.

A. PERFORMANCE OPTIMIZATION

CATALYSTS

Performance comparison between two developmental cathode catalysts (E-3 and E-7) is being provided through the testing of Stack No. 1 and Stack No. 2 in the 1984 series. The performance of these two catalysts remains virtually the same in Stack No. 1 (4000 hours) and in Stack No. 2 (2900 hours).

B. COST REDUCTION

BIPOLAR PLATES EDGE-SEALED WITH FUSED RESIN

The edge-sealing of graphite bipolar plate A-elements using fused resin (see August-October 1983 Quarterly Report) has been successfully reduced to practice with one-ft^2 plates. The scale-up of this method from one-ft^2 to two-ft^2 plates was undertaken during this period. The principal difficulty encountered was the greater length of the two slits parallel to the hydrogen flow direction. The two outboard pieces bordering these slits constitute a long span that creates tensile stresses during the insertion of resin strips into the slits prior to hot-pressing. These stresses caused the outboard graphite strips to break off near the corners of the A-element, causing difficulties in handling and resulting in bowed edges after hot-pressing.

To alleviate the problem, an aluminum fixture was designed and constructed to hold detached edge-strips in place

during resin insertion and hot-pressing. The first experiments with this fixture were not fully successful due to alignment and positioning problems in the hot-press; unacceptable distortion occurred during film-bonding.

The next step will be to design and test a simpler holding fixture whose main function will be to horizontally support the center region of the plate's edges. The outboard graphite sections will now remain connected to the A-element near the corners of the plate. The goal is a fixture strong enough to provide the required support and with geometry compatible with the hot-pressing operation.

LARGER CELL SUB-STACKS BETWEEN COOLING PLATES

The use of five cells per cooling plate is in effect in the two 25-cell, 13 in. x 23 in. stacks (No. 1 and No. 2). Comprehensive thermal data will be obtained later in the test program.

C. RELIABILITY

AUTOMATED ELECTROLYTE-REPLENISHMENT SYSTEM

1983 Stack No. 3 (11-cell, 10.7 in. x 14 in.) continues to operate with an automated electrolyte-replenishment system. This system is performing successfully to date (6900 hours on load).

NON-METALLIC COOLING PLATES

Non-metallic cooling plates continue to operate successfully in 1983 Stack No. 3, above, as well as in 1984 Stack No. 1 and Stack No. 2 (see Task III, above).

TASK V - FUEL PROCESSING SUPPORT

The intent of this task was to provide background data and information to support the design and construction of an optimized 50kW fuel processor under Task III. Most of the effort of this task was devoted to screening and longevity testing of catalysts for steam reforming of methanol. This task is now complete.

TASK VI - IMPROVED ELECTROCATALYSTS

Developmental electrocatalyst formulations are being prepared under Engelhard sponsorship. These are provided to the main program, and results are reported under Task IV.

Development work is being pursued on both cathode and anode catalysts; however, the major activity at the present time is directed toward improved cathode activity (See Task IV).

SECTION III. CURRENT PROBLEMS

None.

SECTION IV. WORK PLANNED

TASK III - ON-SITE SYSTEM DEVELOPMENT

- Continue testing of Stack No. 1 and Stack No. 2.

TASK IV - STACK TECHNOLOGY

- Continue evaluation of electrolyte-replenishment system and non-metallic cooling plates in 1983 Stack No. 3.

- Pursue technology improvements to reduce cell IR-loss.

- 25 CELLS
- 13 IN. X 23 IN.
- 150 A/ft2 (161mA/cm^2)
- 196°C (AVG.)
- 4008 HOURS ON LOAD

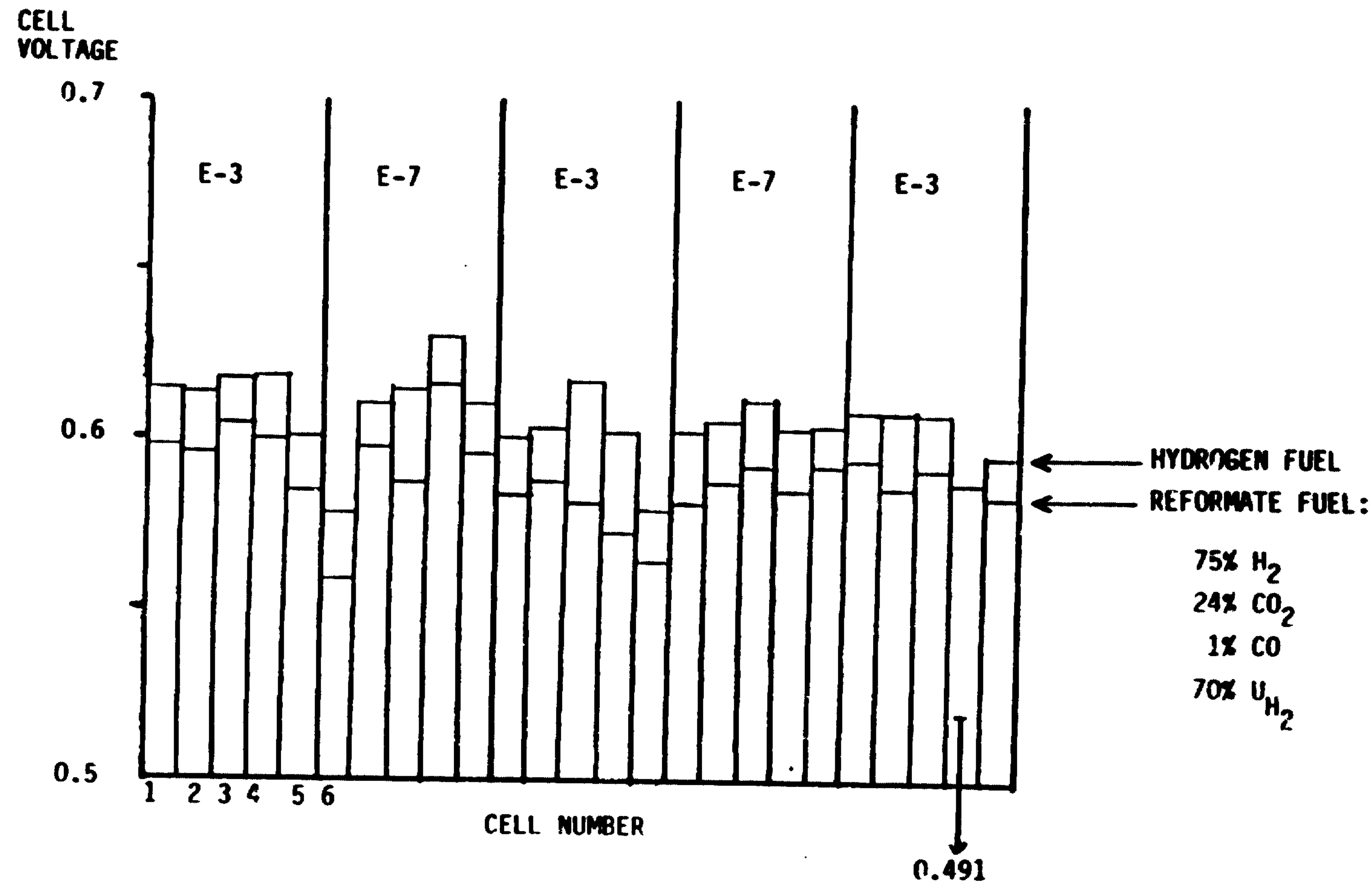

FIGURE 1 CELL VOLTAGES IN STACK NO. 1

SKS

- 25 CELLS
- 13 IN. X 23 IN.
- 150 A/ft^2 (161mA/cm^2)
- 196°C (AVG.)
- 4008 HOURS ON LOAD

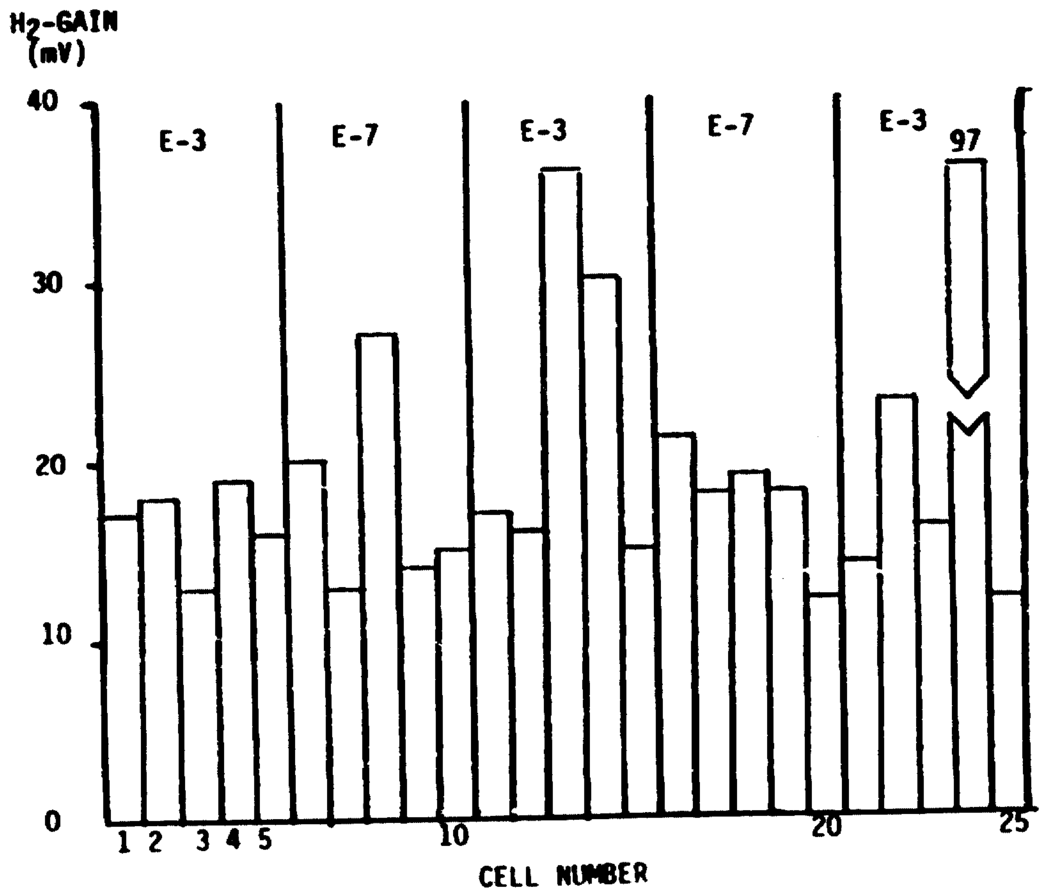

FIGURE 2 H_2-GAIN IN STACK NO. 1

SKS

- 25 CELLS
- 13 IN. X 23 IN.
- 150 A/ft^2 (161 mA/cm^2)
- 192°C (AVG.)
- 2928 HOURS ON LOAD

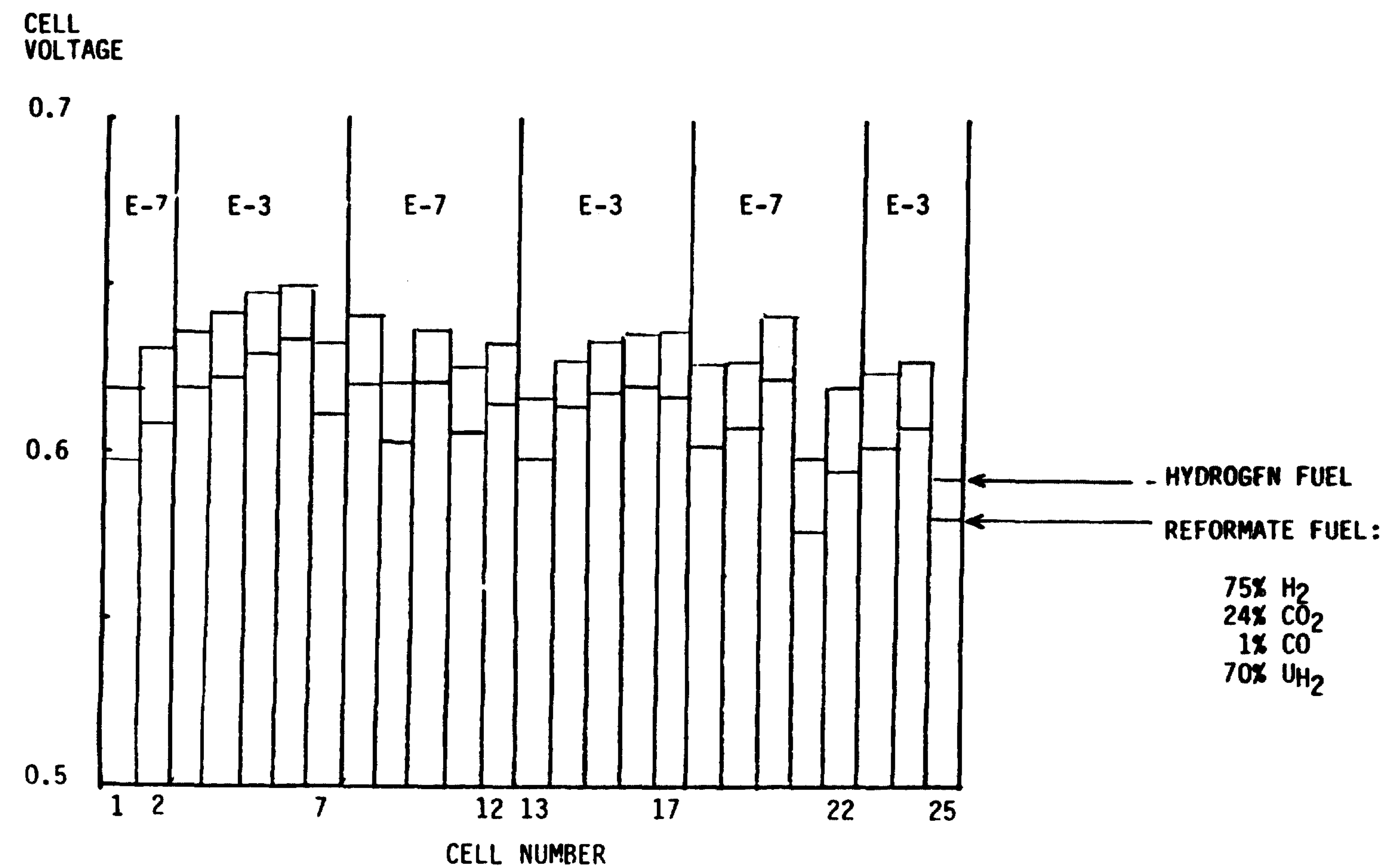

FIGURE 3 CELL VOLTAGES IN STACK NO. 2

SKS

- 25 CELLS
- 13 IN. X 23 IN.
- 150A/ft^2 (161mA/cm^2)
- 192°C (AVG.)
- 2928 HOURS ON LOAD

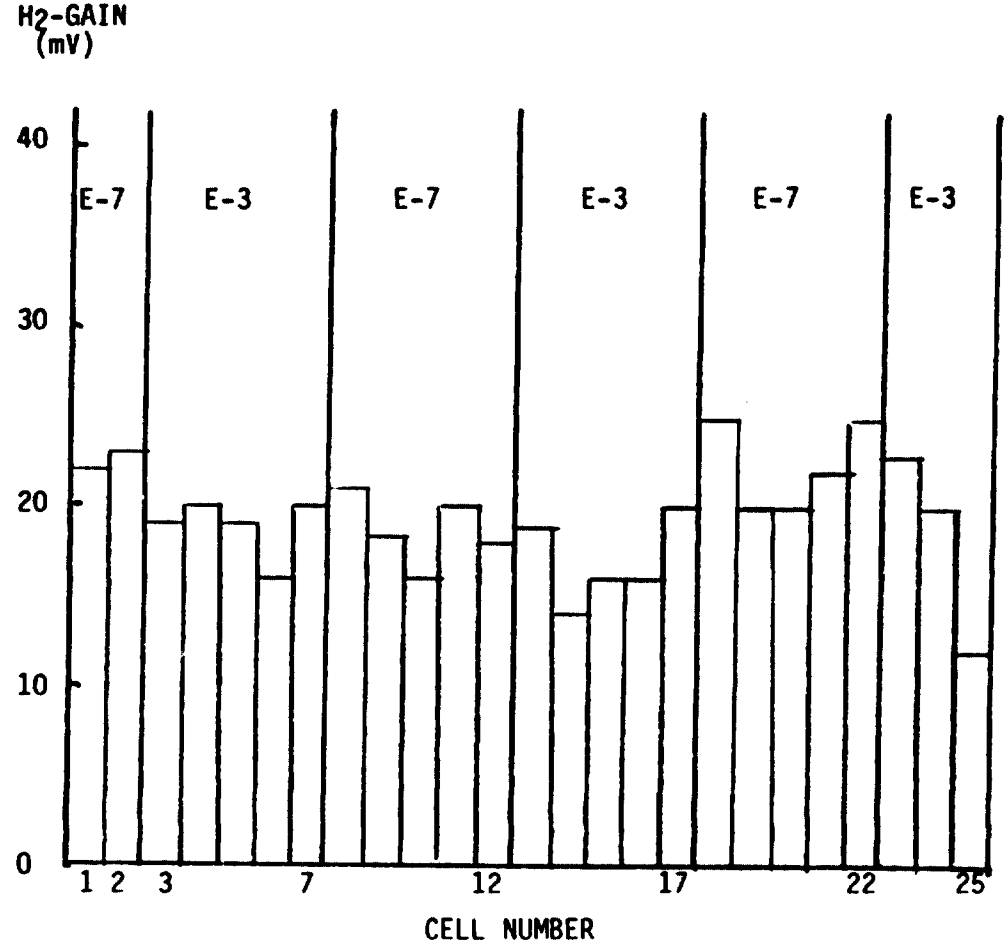

FIGURE 4 H_2-GAIN IN STACK NO. 2

SKS